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(71) Applicant: 000005223
Fujitsu K.K.
1015 Kami-Odanaka, Nakahara-ku,
Kawasaki-shi, Kanagawa

(72) Inventor: Kanae Shimizu
c/o Fujitsu K.K.
1015 Kami-Odanaka, Nakahara-ku,
Kawasaki-shi, Kanagawa

(72) Inventor: Hiroshi Tsukadai
c/o Fujitsu K.K.
1015 Kami-Odanaka, Nakahara-ku,
Kawasaki-shi, Kanagawa

(74) Agent: Sadakazu Itake, Patent Attorney

(54) [Title of the Invention] Laser Processing Mask

(57) [Abstract]

[Objective] The objective is to selectively change the transmittance of laser light in a mask composed of a dielectric multilayer film.

[Structure] This laser processing mask is constructed to allow the transmittance of the laser light to be selectively changed by partially changing the number of layers in the dielectric multilayer film forming the mask.

[Claims]

[Claim 1] For a mask composed of a dielectric multilayer film used in the selective exposure of high power laser light, a laser processing mask features selectively changing the transmittance of laser light by partially changing the number of layers in the dielectric multilayer film forming the mask.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Utilization] The present invention relates to the laser processing mask used in selective exposure by a high power laser, such as an excimer laser.

[0002] The multichip module (MCM) is being developed into a practical method for high density mounting of surface mounted parts that are primarily semiconductor integrated circuits, such as LSI and VLSI. Although there are thin film methods and thick film methods for forming MCM circuit substrates, the thin film method for forming an MCM substrate uses a glass substrate, such as borosilicate glass, and a metal with a low resistance, such as copper (Cu), as the wire material; forms the pattern by using thin film deposition technology, such as sputtering or vacuum deposition, and photolithographic technology; and uses a resin with superior heat resistance and a small dielectric constant (ε), such as polyimide, to form the insulating layer.

[0003] The fabrication of a semiconductor integrated circuit requires, at the very least, signal wires, power supply wires, and ground wires. Because this wiring is complex when multiple integrated circuits are on a chip, the MCM substrate must have a multilayer structure. The lower and upper wiring layers have a structure wherein the circuits are connected by the vias provided in the intervening insulating layers. Laser ablation processing has been focused on as a method for forming vias.

[0004]

[Prior Art] Well-known conventional laser processing methods use YAG lasers (yttrium aluminum garnet laser with a 1.06 μm wavelength) or carbon dioxide lasers (CO_2 laser with a 10.6 μm wavelength) and the thermal energy of the infrared rays. However, these kinds of processing methods produce significant heat damage in the surrounding area. Although the beam must be focused for processing, a small spot diameter is difficult to produce because the light is infrared light. Also, since this is spot processing, it is not suited to fine patterning over a wide area.

[0005] On the other hand, an excimer laser is a gas laser that uses the excitons of a rare gas such as krypton (Kr) or xenon (Xe), and a halogen such as fluorine (F) or chlorine (Cl). Ultraviolet

wavelength laser light, for example, the laser light from KrF with a 248 nm wavelength, XeCl with a 308 nm wavelength, and ArF with a 193 nm wavelength, can obtain a pulse width of several nanoseconds and MW peak output.

[0006] Common organic compounds often have high light absorption in the ultraviolet light region. When light with a strong light pulse (e.g., about 100 MW/cm^2) as in an excimer laser irradiates a material composed of this kind of organic compound and the absorption wavelength of the material matches the laser wavelength, chemical bonds are broken instantaneously and the surface layer evaporates. This phenomenon is called ablation. Ablation processing uses this phenomenon to give a clean finish to the processed cross-section. Because a relatively wide area of 10 mm^2 can be processed at one time, a fine pattern can be formed by exposure through a mask.

[0007] Chromium (Cr) metal masks are used with argon (Ar) lasers and helium-neon (He-Ne) lasers. However, if metal masks are used with a high power laser like an excimer laser, damage is caused by the evaporation of metal, so metal masks cannot be used. Consequently, masks fabricated from dielectric multilayer film are used.

[0008] Figure 3 shows the structure of the dielectric multilayer film. Two transparent dielectrics A and B with different refractive indices are alternately formed into multiple layers, each layer having a thickness of one-half the wavelength of the irradiating light 1 (124 nm for a KrF excimer laser), to produce the dielectric multilayer film 2. Since Bragg reflection is used, a reflectance near 100% can be achieved by increasing the number of layers.

[0009] Usually, silicon dioxide (SiO_2, 1.48 refractive index) and yttrium oxide (Y_2O_3, 1.91 refractive index) are combined for use as materials A and B because the quality of these films is good, and they are transparent to excimer lasers. Also, the difference between their refractive indices is large. This combination is used in optical systems requiring multiple reflections, such as laser resonators.

[0010] Next, Figure 2 is a schematic showing the ablation processing method. In this structure, the laser light 4 generated by the excimer laser light source 3 is directed by the mirror 5 to the first lens 6 for focusing, is focused by the second lens 7 to the required beam diameter, and irradiates the dielectric multilayer film (mirror mask) 8.

[0011] The mirror mask 8 patterns the dielectric multilayer film 2 on the transparent quartz substrate 9. The resin film 10 for ablation processing forms a film on a substrate 11 made of, for example, borosilicate glass. After the mirror mask 8 and the substrate 11 are fixed to the frame 12, they are positioned on the X-Y stage 13 to form a movable structure.

[0012] In this case, the dielectric multilayer film 2 of the mirror mask 8 has holes opened only at the via-forming positions 14 to the transparent quartz substrate 9. When several hundred pulses

are irradiated at an exposure intensity of 1 J/cm^2 per pulse by the excimer laser light source 3, the resin film 10 being irradiated by the laser is laser ablated to form the via holes 15.

[0013]

[Problem Which the Present Invention Attempts to Solve] The thin film multilayer circuit substrate exemplified by the MCM substrate provides multiple conducting layers, such as signal layers, power supply layers, and ground layers, for forming an electronic circuit. A resin having a high insulating resistance and a low dielectric constant, such as a polyimide, is used between the conducting layers to form the interlayer insulating layer. To form the electronic circuit, vias are provided at the required positions to connect the upper and lower wires.

[0014] The requirements in forming this kind of multilayer circuit substrate are as follows:
(1) Fine wires should be patterned with high precision.
(2) The vias should be accurately formed at their positions.
(3) There should be no peeling between the wiring and the insulating layer.
In (1), this measure uses thin film forming technologies, such as sputtering, and photolithographic techniques to precisely form fine wires made of copper (Cu), etc.

[0015] In (2), since the ultraviolet light hardened polyimide is practical and laser ablation processing is possible, the vias can be accurately formed at their positions. In (3), by sputtering to produce a Cr thin film and forming a Cu film on top, the adhesion to the insulating layer is improved.

[0016] However, resin and metal have different thermal expansion coefficients. For example, in contrast to the linear expansion coefficient for polyimide of $1.8 \times 10^{-5}/K$, the linear expansion coefficient for Cr is $8.4 \times 10^{-6}/K$. Moreover, the semiconductor integrated circuits mounted on a thin film multilayer circuit substrate generate heat during operation. Consequently, a thin film multilayer circuit substrate frequently has a thermal cycle. Originally, resin and metal did not adhere well to each other, so the wiring easily peeled. Therefore, one method to physically improve the adhesiveness between the two is to selectively coarsen the surface only at the positions for forming the wire patterns in the insulating layer. The problem is determining this method.

[0017]

[Means Used To Solve the Abovementioned Problem] The abovementioned problem can be solved by selectively changing the transmittance of the laser light by partially changing the number of layers in the dielectric multilayer film forming the mask to make the laser processing mask and coarsen the wire pattern forming region.

[0018]

[Operation] The present invention adjusts the number of layers in the dielectric multilayer film of the mirror mask used in laser ablation processing to change the intensity of the laser light in some parts. Weak ablation coarsens the surface of the insulating layer.

[0019] Figure 1 shows the cross-sectional view (A) of the mirror mask and the resin film and the top view (B) of the resin film in an implementation of the present invention. Figures (A) and (B) have corresponding positional relationships. A conventional mirror mask had a constant number of structural layers in the dielectric multilayer film 20, and the dielectric multilayer film 20 was not provided in the hole 21 that passed the laser light. In other words, the structure allowed the laser light to be completely reflected by a portion of the mask, and pass through the hole with no attenuation. On the other hand, the mirror mask according to the present invention provides a dielectric multilayer film 22 with few layers in some parts and performs weak ablation processing by transmitting the attenuated laser light.

[0020] (B) in the same figure shows the wire pattern forming positions that have two via holes 15. In later processes, a Cr/Cu thin film is formed on the resin film 19, the via holes 15 are filled, and the photolithographic techniques form the wire patterns in the shape of a dumbbell. In this case, in order to improve the adhesiveness between Cr and the resin film 19, coarsening the surface of the resin film 19 only at the positions where wires will be formed is effective.

[0021] As shown by the mirror mask 18 in (A) in the same figure, the method used in the present invention does not provide the dielectric multilayer film at the holes 21 in the mask which form the vias 15, but does provide a dielectric multilayer film 22 with fewer layers in the wire pattern forming position 23 in this area. If laser light 4 is irradiated in the conventional way, the resin film 19 on the substrate 11 is ablated, and the via holes 15 are formed. In addition, the wire pattern forming positions 23 are lightly ablated to coarsen the surface of the resin film.

[0022]

[Embodiments] An embodiment is explained using Figures 1 and 2. First, sputtering is used to successively form the SiO_2 film and Y_2O_3 film each with a 0.124 μm thickness as the dielectric multilayer film on the transparent quartz substrate 9. The mirror mask 18 is formed with 50 layers of dielectric multilayer film 20 as the mask, 0 layers at the holes 21 for forming via holes, and 10 layers of dielectric multilayer film 22 corresponding to the wire pattern forming positions. A hole 21 has a 10 μm diameter, and a wire pattern forming position has a 20 μm width, and a 100 μm length.

[0023] After polyamic acid is coated on the substrate 11 composed of borosilicate glass and the solvent dries, curing at 360°C forms the resin film 19 from a polyimide with a 20 μm thickness. After the mirror mask 8 and the substrate 11 are fixed to the frame 12 as shown in Figure 2, they are positioned on the X-Y stage 13.

[0024] Next, a KrF laser oscillator is used as the excimer laser light source 3. The laser light 4 with a 248 nm oscillation wavelength, 16 ns pulse width, and 250 mJ/pulse output irradiates 200 pulses for laser ablation. As a result, via holes 15 with clean edges and a 10 μm diameter can be produced. The wire pattern forming position 23 in this area is coarse, and the surface roughness is 0.5 to 1.0 μm.

[0025]

[Effects of the Invention] According to the present invention, the intensity of the laser light irradiating a resin film can be accurately and selectively changed. Not only can holes be opened, but the surface can be coarsened to provide the resin film with excellent adhesion to fine wire patterns.

[Brief Explanation of the Figures]

[Figure 1] (A) is the cross-sectional view showing the implementation of the present invention and (B) is the top view of the resin film.

[Figure 2] This schematic shows the ablation processing method.

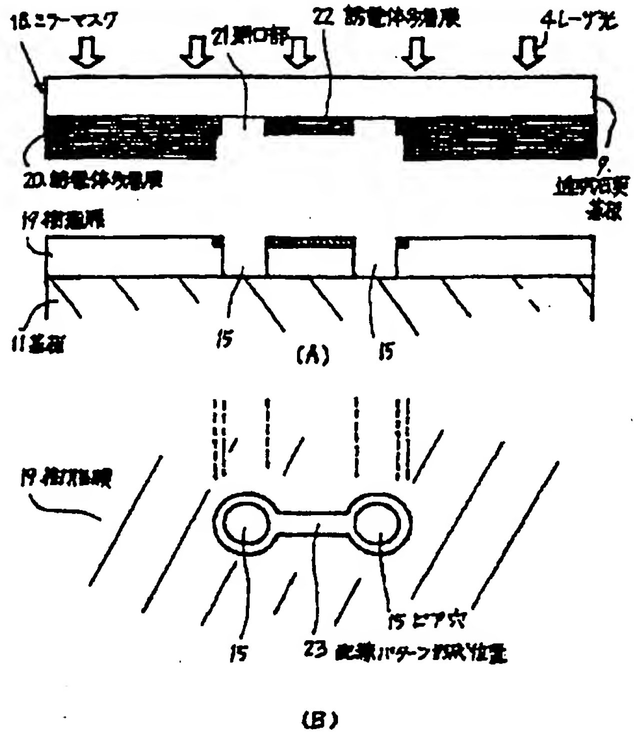
[Figure 3] This schematic shows the dielectric multilayer film mask.

[Explanation of Symbols]

2	Dielectric multilayer film
4	Laser light
8, 18	Mirror mask
10, 19	Resin film
15	Via hole
20, 22	Dielectric multilayer films
23	Wire pattern forming position

[Figure 1]

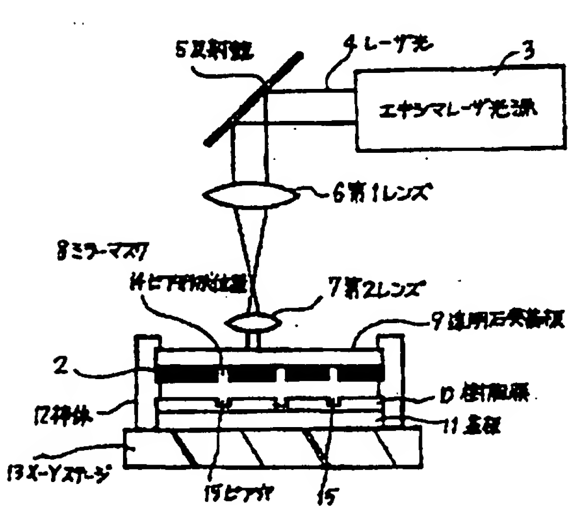
(A) Cross-sectional view showing the implementation of the present invention and (B) top view of the resin film



4: Laser light, 9: Transparent quartz substrate, 11: Substrate, 15: Via holes, 18: Mirror mask, 19: Resin film, 20: Dielectric multilayer film, 21: Hole, 22: Dielectric multilayer film, 23: Wire pattern forming position

[Figure 2]

Schematic showing the ablation process



3: Excimer laser light source, 4: Laser light, 5: Mirror, 6: First lens, 7: Second lens, 8: Mirror mask, 9: Transparent quartz substrate, 10: Resin film, 11: Substrate, 12: Frame, 13: X-Y stage, 14: Via-forming position, 15: Via hole

[Figure 3]

Schematic showing the dielectric multilayer film mask

1: Irradiating light, 2: Dielectric multilayer film